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COLLEGE OF AGRICULTURE.  
AGRICULTURAL EXPERIMENT STATION.

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# GRASSHOPPERS IN CALIFORNIA.

By C. W. WOODWORTH.



YOUNG GRASSHOPPER ON BLADE OF GRASS.  
(Slightly enlarged).

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## GRASSHOPPERS IN CALIFORNIA.

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Grasshoppers or locusts have, during the last season, caused a great deal of alarm in the minds of fruit-growers in this State, though the losses sustained have not been particularly large. Hoppers were moderately abundant over a very large area, including both sides of the Sacramento and San Joaquin valleys; and in southern California in a few places in Santa Barbara and Ventura counties and in the hill regions of San Diego County. The presence of considerable numbers of hoppers over such a large extent of territory in a single season is quite remarkable. The actual numbers present in each of these regions was a great deal less than had been known in previous years. Had the numbers been as great as they have formerly been in all these same regions, the total amount of injury would have been enormous.

It is not known exactly what the conditions are that have favored the unusual increase of hoppers this year, but in every region where migratory locusts are prevalent this same sudden increase in seasons favorable to them is the common experience. The increase of the insects this year simply emphasizes the fact that California is one of the regions where the conditions are favorable to migratory locusts. In every part of the world where there is an arid climate, where grass-covered highlands exist with neighboring cultivated lowlands, migratory locusts abound and do injury, the extent of which depends primarily upon the season but also upon the extent of this bare arid upland country, and upon its proximity to the cultivated lands.

The open pasture lands in California are very widely scattered over the State and are in the aggregate quite extensive, though very insignificant as compared with those on the other side of the Rocky Mountains. While we will not, for this reason, expect as great grasshopper migrations as have occurred there, still our orchards and vineyards are each year coming closer and closer to the breeding-grounds. These interests can be so seriously injured by grasshoppers that the question of grasshopper control is even now a matter of extreme importance, the solution of which is becoming more and more imperative.

*Change of Law Imperative.*—We will attempt in this bulletin to present a review of the present knowledge of the hopper situation in this State, and to show that there is ground for believing that the danger from this insect could be almost entirely avoided if the proper pro-

visions were made for the study of the problem and for the carrying-out of a sound general policy in accordance with the facts so determined. At the present time the laws are such as to really prevent any concerted action; and no one has the exact knowledge of the breeding-grounds or the habits of the insects there, to intelligently direct such action. This year's experience has indicated very clearly the needs of a hopper investigation and control.

#### GRASSHOPPERS THIS YEAR.

About the first of June reports of injury were received from several widely separated regions. In the lower San Joaquin Valley the grasshoppers had already begun to obtain wings, but there was no true migration; indeed, nowhere this year has there been serious injury from migratory swarms, the whole work being done by drifting swarms in regions immediately adjacent to the breeding-grounds. The hopper invasion in Sacramento County received the most public attention, though the greatest injury was done in Fresno and Tulare counties.

*Grasshoppers at Roseville.*—The Placer County swarm was first investigated by W. T. Clarke, assistant entomologist of this Department, who

was called into consultation in reference to the injury done in the vicinity of Roseville. As a result of his studies he was able to show that the orchards and vineyards adjacent to Roseville were threatened by a comparatively small swarm which bred in the pasture lands north and east of town. Fig. 1 illustrates the situation at the time his investigations were made. He called a public meeting at Roseville on June 9th, at which he urged that measures be at once taken to attack the hopper

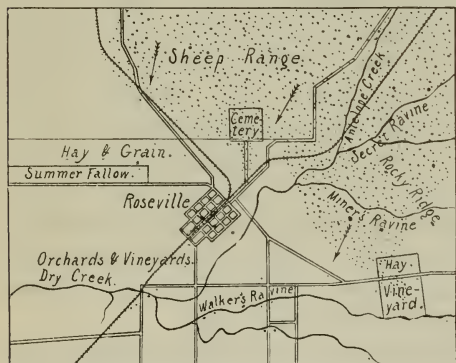


FIG. 1. MAP SHOWING THE ROSEVILLE SWARM OF GRASSHOPPERS, JUNE 9, 1902.

The arrows indicate the direction taken by the hoppers.

upon its breeding-ground, showing that in this way the whole situation in that district could be handled. He advised the use of the hopper-dozer and the burning of a very narrow strip of pasture nearest the cultivated fields.

Instead of doing this themselves, the parties interested finally decided to call upon the county horticultural commissioners to order the owners of the infested territory to suppress the hoppers. This the commissioners did, and on the refusal of the owners they prepared to carry out the plan proposed at the meeting. Because of threats that



were made they first sought legal advice, and learned that they might be personally responsible for damages to the burned pastures. Thereupon they very naturally refused to act. According to the advice obtained, their powers in the matter were very doubtful, if existing at all; and thus the matter rested, with nothing done, for two or three weeks. In the meantime the hoppers continued to drift over the cultivated lands, doing scarcely any injury to grain crops, because the grain at this time was nearly all ripe, but destroying some vineyards and isolated orchard trees, the owners of which, as a general thing, did not attempt to save them in any effective way. Fig. 2 will show how completely the leaves may be stripped from vines.



FIG. 2. VINEYARD NEAR ROSEVILLE, SHOWING WORK OF GRASSHOPPERS.  
From photograph taken in June, 1902.

*Grasshoppers at Fair Oaks.*—The next point at which hoppers caused apprehension in this district was in the vicinity of Fair Oaks, in Sacramento County. Here the hoppers were quite numerous, and threatened to do a great deal of damage. The people in this community became thoroughly aroused, and at a series of public meetings decided that the adjacent breeding-grounds should be burned over. They appealed to the County Supervisors for power to do this work. The prompt and decided action of the members of this Board showed their public spirit, for they at once authorized and directed the people owning the threatened orchards to undertake the matter. This action was taken in spite of the fact that there was considerable doubt as to the legality of the action, and therefore considerable individual risk on the part of the Supervisors for suits of damage.

Work in this region was greatly facilitated by the public spirit also of one of the largest land-owners of that district, who freely consented to the destruction of the grass on his holdings. A large area in this way was burned over, and the immediate danger to the orchards of Fair Oaks and Orangevale was entirely overcome. The whole community turned out to do this work. Fig. 3 shows a gang of men with hoes clearing a line through the grass preliminary to starting a fire.

More or less friction occurred in some of the districts where this burning was done, and some of the troubles were carried into court. Because of the lack of careful inspection it is more than possible that burning was done over a great deal of territory on which there was not sufficient



FIG. 3. THE PREPARATION OF THE "FIRING LINE" IN THIS SEASON'S CAMPAIGN.

infestation of hoppers to justify the work. It is almost certain, also, that in some of the burning, carelessness resulted in losses that might have been entirely avoided; but at best, burning is accompanied by more or less risk. It is also true that other means, as for instance the use of the hopper-dozer, would have been equally effective and cheaper, without the loss of any of the pasturage. In spite of all these criticisms of the work in Sacramento County, no one who was conversant with the situation there this summer can have any doubt that great loss to the fruit interests of that part of the county was avoided by these measures.

The inadequacy of the laws now in existence to meet an invasion of hoppers is very clearly shown; for it is doubtful if another Board of Supervisors could be found in the State that would have the temerity



to take the matter in its own hands, as was done in Sacramento County; and without such boldness absolutely nothing could be done concertedly under our present law.

*Attempted State Work.*—After the ground in the neighborhood of Fair Oaks and Orangevale had been burned over, the people in those communities very naturally began to be somewhat alarmed by the possibility of flying swarms from the immediately adjacent breeding-grounds of Placer and El Dorado counties. A committee of Supervisors of Sacramento County, together with the District Attorney, held conferences with the Supervisors of these two adjacent counties, and urged them in the strongest possible manner to take similar action in their respective districts. The Supervisors of neither of these counties saw fit to take the action desired, so nothing along this line could be accomplished. If the hoppers had been slightly more abundant, so that there might have been flying swarms, there is quite a possibility that these orchards in the Fair Oaks and Orangevale colonies would have been destroyed in spite of the very energetic and expensive work that was done for their protection in their immediate neighborhood.

Failing to accomplish anything in these counties, the Supervisors of Sacramento County appealed to the State Board of Horticulture to exercise what power they imagined might rest in the State Board to defend Sacramento County from the hoppers of Placer and El Dorado counties. The State Board of Horticulture could do nothing, because the law creating this board is so framed as to expressly prevent it. This has been repeatedly so decided by attorneys, and is in accord with the advice of the Attorney-General of the State.

Being unable to do anything but to recognize the importance of the matter, the members of the Board residing at Sacramento, together with the chairman of the Board of Supervisors of Sacramento County, appealed personally to the Governor to use the power which, in the opinion of the Attorney-General, rested alone in the Chief Executive of the State. The Governor, after carefully considering the matter, suggested to the members of the State Board of Horticulture that they undertake the burning of the breeding-grounds in these counties, after first securing from the owners a contract permitting the work to be done, the Governor agreeing to recommend to the Legislature a bill appropriating an amount not to exceed \$10,000 to reimburse those whose grounds were thus burned over. It seemed to all parties of the conference that this action would accomplish all that was necessary, it being believed that even though the consent of part of the owners of pasture lands could not be obtained, still sufficient work could be done to decrease the number of hoppers to a point where the probability of flying swarms would be very slight. This measure was never carried out, owing to the legal advice to the effect that in case the State Board

ordered work to be done under this arrangement, the individual members would be responsible for any accidental fires that might result from the burning of these lands.

While these various propositions were being discussed, the hoppers were growing and obtaining their wings, and had, to quite a large extent, left their breeding-grounds; and were drifting in adjacent stubble fields and occasionally injuring orchard property. They had reached a point where the burning of the breeding-grounds would have but little effect. We therefore advised those who were still trying to find a way to get the work done, that it would then be of doubtful utility, and the effort ceased. The fighting of the drifting swarms was taken up with considerable success. Commonly it was necessary to go into the fields, do the work, and get results, before the growers in a community would try to help themselves in an effective way.

Fortunately, as has already been said, flying swarms did not occur this year, so that the total injury resulting was in the immediate neighborhood of the breeding-grounds. It is doubtful if, in this year, any considerable numbers of hoppers crossed county lines, but if there had been flying swarms, the need of State control would have been still more evident.

#### NEED OF LEGISLATIVE ACTION.

The account just given of the grasshopper situation this year, clearly brings out the necessity for concerted action, for providing the means of securing greater knowledge of the insect, and for adequate laws to deal with the hoppers in years when they are really highly injurious. There is no doubt whatever that each succeeding grasshopper-year will bring the need of community action, and a demand for it that can not be denied. Orchard interests are too great to permit the destruction of any considerable areas of growing trees or vines when there is any hope that by prompt action these losses can be greatly decreased or entirely avoided. If left to go on as it is, there will be the demand on the part of the fruit-growers each hopper-year that infected pasture land be burned over, and this burning may at times cause more actual loss than the saving through the destruction of the hoppers. It will be as much to the interest of the owner of pasture lands as of the orchardists, that the matter be settled now, and settled right. The things to be done to bring this about are, first, to provide for obtaining the facts relative to the location of the breeding-grounds, and the habits of the various species of locusts; second, the securing each year of enough information to allow the use of the most economical means for the destruction of the hoppers, and for provision for compensating those whose property it may be necessary to injure in the work; and, third, careful and com-

petent supervision of every general effort communities may desire to make for their protection. The details for this work will be presented at the close of this bulletin.

#### THE INSECTS CONCERNED.

The name grasshopper or locust is applied to a large number of insects, many of which have never been of much economic significance. Usually the really destructive locusts in any country belong to a single species. In California generally one species will greatly predominate in a swarm, though usually our swarms are not confined to a single kind. In some seasons one species will become abundant, and in another a second may be the most common; and during the same season one species may do injury over one section of the State, while a different species prevails elsewhere. During the past season at least half a dozen different kinds did injury in some part of the State. Other kinds which were not troublesome this season have been destructive in former years. The situation is thus very complicated, because these different kinds of grasshoppers have quite different habits and peculiarities, and will require somewhat different conditions to develop them into destructive numbers. All of them must be carefully studied to make our knowledge extensive enough to plan for their best control.

*Insects Falsely Called Locusts.*—A great deal of misunderstanding arose this year in regard to the habits of the grasshoppers, on account of the confusing of this insect with another and entirely different creature found only in the Eastern States, to which the name locust is commonly though incorrectly applied. The so-called "17-year locust" of the Eastern States is a sap-sucking insect, the young of which feeds on the juices of the roots of plants and requires seventeen years for full development. The sudden appearance of the adults of this insect doubtless suggested to the Puritan fathers who had never lived in a country subject to locust invasions, that this creature was the locust of the Bible. At any rate, in no other country is the term locust applied to any member of the order to which it belongs.

In California we have a couple of rather common members of the family Cicadidæ, the harvest fly family, to which the so-called 17-year locust belongs. These are illustrated in Fig. 4. The larger species belongs to the same genus as the seventeen-year species, but as far as we know both our species require but a single year for their full development.

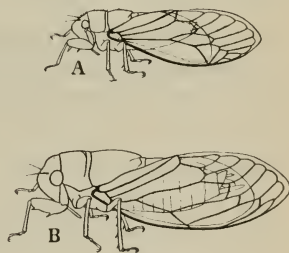


FIG. 4. HARVEST FLIES.  
(A) *Platypedia areolata* Uhl.  
(B) *Tibicen rimosa* Say.



*True Locusts and Their Relatives.*—The only insects that have any right to the name locust or grasshopper belong to the order Orthoptera. These two names are usually applied interchangeably to all the members of the family Acrididæ and to such members of other families as are not clearly distinguished from them, by people in general. Indeed, some of the members of the family Locustidæ seem to have almost earned the name by living and feeding in company with grasshoppers and doing the same sort of injury.

We give below a list of all the kinds of grasshoppers known to exist in the State, together with the other members of the Order. The differ-

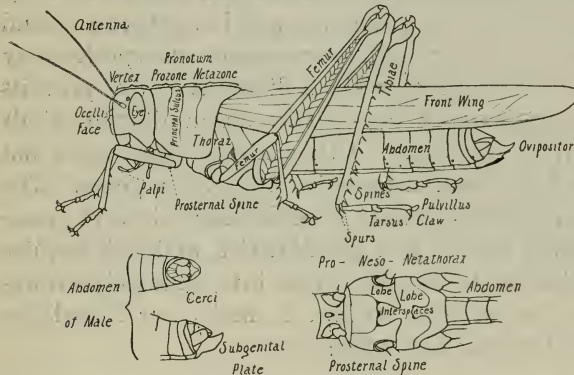


FIG. 5. SCHISTICERA VENUSTA SCUD., THE LARGEST OF THE INJURIOUS SPECIES THIS YEAR.

ences between the different kinds are also given in the form of synopses, for the benefit of any who may wish to study grasshoppers carefully and who desire to determine their names. Most of the technical terms it was necessary to use

are shown on Fig. 5. The work of finding these names will be much easier if one first makes quite a collection of these insects so as to be able to make comparisons.

The families of Orthoptera may be distinguished as follows\*:

Body as thick as broad, (a); -flattened. Ending in a pincer behind, *Forficulidæ*; -not, *Blattidæ*. —(a) Hind legs enlarged for leaping, (b); -not. Front legs enlarged for grasping, *Mantidæ*; -not, *Phasmidæ*. —(b) Antennæ shorter than the body, *Acrididæ*; -longer. Feet four-jointed, *Locustidæ*; -three-jointed, *Gryllidæ*.

**BLATTIDÆ.**—Cockroaches are great pests indoors, but, except in the more northern part of the State, are rather rare insects. Many tropical species often come here in banana bunches, but do not long survive in this climate. Only four species have been recorded in this State, distinguishable as follows:

All the femora strongly spined beneath, *Stylopyga orientalis* Linn. -front femora almost devoid of spines beneath, *Blatta germanica* Linn. (Fig. 5, A); -none spined beneath. Winged, *Planchora hyalina* Saus.? -wingless, *Cryptocercus punctulatus* Scud.

\*These synopses are to be used as follows: Suppose one would determine the family name of a cricket. He reads the first character, and as the body is as thick as broad, he goes to section —(a), and as the hind legs are enlarged for leaping, goes to —(b), and as the antennæ are longer than the body and the feet are three-jointed, he arrives at the family name *Gryllidæ*.



FORFICULIDÆ.—Earwigs are credited with injury to flowers in other countries, but have not caused complaint here. They live in damp situations and feed mainly on decaying vegetation. We have two species: *Sphingolabis californica* Dohrn (Fig. 6, B) and *tæniata* Dohrn, the latter possessing oblique ridges on the second abdominal segment above.

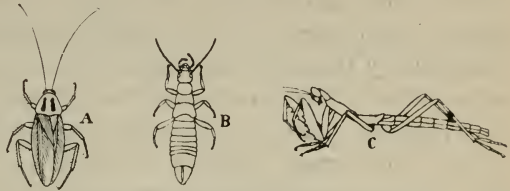


FIG. 6. ORTHOPTERA THAT DO NOT HOP.

(A) *Blatta germanica* Linn. (B) *Sphingolabis californica* Dohrn, young. (C) *Litaneutria pacifica* Scud., young.

PHASMIDÆ.—“Walking sticks” feed on vegetation in much the same way as

grasshoppers, but can not leap nor migrate, being wingless. The eggs are dropped loosely on the ground. We have two species: *Sermyle arbuscula* Rehn. and *Timema californicum* Scud., the latter distinguished by possessing two spines between the eyes.

MANTIDÆ.—Mantids feed on other insects, which they capture by means of their greatly developed front legs. They will eat each other so readily that they never become abundant enough to be of much service in killing injurious insects. The two species recorded as occurring here are *Litaneutria pacifica* Scud. (Fig. 6, C) and *obscura* Scud., the latter distinguished by having a large black spot near the base of the hind wing.

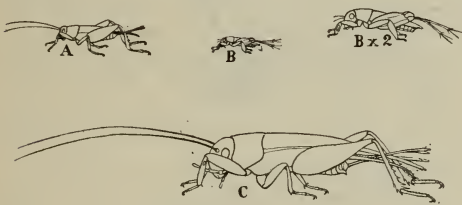


FIG. 7. CRICKETS.

(A) *Nemobius mexicanus* Walk. (B) *Tridactylus minutus* Scud. (C) *Gryllus vocalis* Scud.

GRYLLIDÆ.—Crickets are not very abundant in California, though some species do occasionally become quite abundant locally. Some of the swarms called in former years grasshoppers, were really crickets, and often wingless grasshoppers are called crickets. The following tables will enable one to distinguish our species:

Front legs suited for digging, (a); -not. Body subspherical, *Myrmecophila formicarium* Scud. -much longer than broad. Hind tibiæ saw-toothed between the spines, *Ecanthus californicus* Scud. -not. Spurs on hind tibiæ movable, *Nemobius*; -fixed. Ear on front leg large, *Gryllus*; -small or wanting, *Myogryllus sicarius* Scud. -(a) Two ocelli, *Gryllotalpa cultriger* Uhl. -three, *Tridactylus*.

*Tridactylus*. Length over 5.5 mm., *apicalis* Say.; -less, *minutus* Scud. (Fig. 7, B).

*Nemobius*. Hind wings long, *neomexicanus* Scud. -wanting, *mexicanus* Walk. (Fig. 7, A).

*Gryllus*. General color yellowish brown, *assimilis* Fabr. -blackish. Front wings yellowish brown, *integer* Scud. -black. With light-colored shoulder stripes, *vocalis* Scud. (Fig. 7, C); -without, *pennsylvanicus* Burm.

LOCUSTIDÆ.—True katydids, those possessing wings by means of which the males produce shrill notes, are not at all common in this State, but there are a considerable number of more or less cricket-like wingless forms. Some of the latter are found in company with true grasshoppers, feeding in the same way and drifting with them into cultivated fields. Occasionally they will become so abundant as to constitute the bulk of the swarms. They are unable to migrate, as all having these habits are wingless. Quite a number of these insects live in the ground like crickets, the largest example of which has received the name "potato bug" by many growers, on account of its injury to this tuber. The egg-

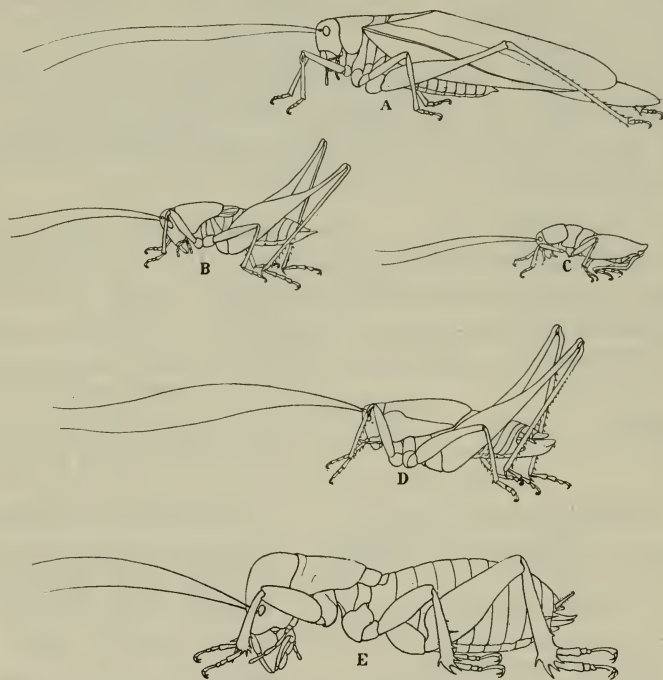


FIG. 8. KATYDIDS.

(A) *Scudderia furcifera* Scud. (B) *Anabrus simplex* Hald. (C) *Ceuthophilus pacificus* Thom.  
(D) *Ateloplus notatus* Scud. (E) *Stenopelmatus irregularis* Scud.

laying habits are very different in the various members of the family. Some of the larger winged forms arrange their eggs in two regular rows on a twig, and are often mistaken for some strange form of scale insect. The genera occurring in California may be distinguished by the following tables:

Wingless, (c); -with short useless wings, (b); -with wings suitable for flight. Hind tibiæ with no spines on inner side, (a); -spines present on both sides. Both pair of wings equal in length, *Platylyra californica* Scud. -unequal, *Scudderia*. -(a) Front and middle tibiæ with spines beneath, *Conocephalus acutulus* Scud. -unarmed. Ovipositor straight or male subgenital plate excavate, *Orchelimum agile* DeG. -ovipositor curved or plate truncate, *Xiphidium*. -(b) Prosternum armed with two spines, *Tropizaspis*;

four spines, *Capnobotes*;—unarmed. Front tibiæ spined above on both margins, *Anabrus simplex* Hald. (Fig. 8, B);—on outer margin only. Only one such spine, *Ateloplus notatus* Scud. (Fig. 8, D);—four spines, *Clinopleura melanopleura* Scud.—three spines. Lateral carinæ of pronotum divergent behind, *Idionotus brunneus* Scud.—subparallel, *Steiroxys borealis* Scud.—feebly present behind, *Idiostatus*;—entirely wanting, *Cacopterus*.—(c) Pulvilli wanting, *Stenopelmatus*;—pulvilli present. Hind tibiæ spined on both sides, *Tropidischia xanthostoma* Scud.—unarmed beneath. Front tibiæ hollowed out above, *Gammarotettix bilobatus* Thom.—not hollowed out. Palpi long, *Ceuthophilus*;—short. Third joint as long as the fifth, *Phrixocnemis validus* Scud.—shorter, *Udeopsylla nigra* Scud.

*Scudderia*. Hind femora nearly as long as the wing, *mexicana* Saus.—much shorter, *furcifera* Scud. (Fig. 8, A).

*Xiphidium*. Hind femora spinose beneath, *spinosum* Scud.—not. Vertex more than half as wide as the distance between the eyes, *occidentale* Scud.—less, *vicinum* Scud.

*Tropizaspis*. Lateral carinæ of pronotum divergent from head backward, *ovata* Scud.—converging and then diverging. Hind femora one and one half times as long as pronotum, *castanea* Scud.—about twice. Pronotum widest far behind the middle of metazona, *steindachneri* Herm.—scarcely behind middle, *diabolica* Hald.

*Cacopterus*. Pronotum with slight lateral carinæ behind, *femorata* Scud.—none. Pronotum with a slight posterior sinus, *equalis* Scud.—none, *fuscopunctata* Scud.

*Capnobotes*. Metazona considerably elevated above prozona, *bruneri* Scud.—scarcely, *occidentalis* Thom.

*Idiostatus*. Length of body 30 mm., *bilineatus* Thom.—25 mm., *hermani* Thom.

*Ceuthophilus*. Hind tibiæ strongly arcuate, (*a*);—straight. Front femora a third or more longer than the pronotum, *celatus* Scud.—scarcely longer. Hind femora no wider at the middle than at the base, *vinculatus* Scud.—twice as wide, *californianus* Scud.—(*a*) Middle femora with a long spine near tip, *pacificus* Thom. (Fig. 8, C);—short spine or none, *henshawi* Scud.

*Hemiudeopsylla*. Length of body 10.5 mm., *californiana* Saus-Pict.—18 mm., *platyceps* Saus-Pict.

*Stenopelmatus*. Hind tibiæ with three spines on inner margin above, *pictus* Scud.—four, *histris* Saus.—five. Hind tibiæ about twice as long as pronotum, *longispina* Brun.—about one and one half times as long. Apical spine on inner margin above of hind tibiæ about as large as preceding, *oculatus* Scud.—markedly smaller. Interspace between spine 3 and 4 of this series larger than between others, *irregularis* Scud. (Fig. 8, E);—spines equidistant, *californicus* Brun.

ACRIDIDÆ.—Grasshoppers constitute by far the largest family in the order and contain the most injurious species. Five subfamilies are represented in California, as follows:

Pronotum extending to tip of abdomen, *Tettiginæ*;—only to base of abdomen. Antennæ shorter than front femora, *Mastacinæ*;—longer. Prosternum with distinct spine, *Acridinæ*;—unarmed. Face rounding into vertex, or if slightly angled foveæ of vertex wanting, *Edipodinæ*;—angled or with distinct foveæ, *Truxalinæ*.

*Tettiginæ*.—Very small and rare grasshoppers that live in damp situations. They have never been known to attack cultivated plants. Eight species are known in California.

Vertex advanced beyond the eyes, (*a*);—not. Narrowed anteriorly, *Telmatettix*;—not, *Paratettix*.—(*a*) Vertex wider than one of the eyes, *Tettix granulatus* Scud.—equal, *Merotettix pristinus* Morse.

*Telmatettix*. Lower angle of the side of pronotum acute, *aztecus* Saus. (Fig. 9, A);—obtuse. Body rather coarsely granulate, *aridis* Hanc.—smooth, *hesperus* Morse.

*Paratettix*. Middle femora slightly lobate beneath, *morsei* Hanc.—strongly. Wings undeveloped, *toltecus* Bol.—fully developed, *mexicanus* Bol.

*Mastacinæ*.—This subfamily contains a single recently discovered rare species, *Morsea californica* Scud.



*Truxalinæ*.—None of the members of this subfamily has as yet been recognized as forming any important part of a destructive swarm in this State. Two or three of the species are quite common, however, and might at any time therefore become injurious.

Top of head strongly bent up from pronotum, *Ligurotettix coquilletti* McN. —distinctly though rather feebly, *Gymnes punctatus* Scud. —not at all. Antennæ nearly cylindrical or somewhat flattened, (*a*); —triquetrous. Inner spurs of hind tibiæ unequal, *Opeia testacea* Scud. —equal. Front wings longer than the abdomen, *Horesidotes cinereus* Scud. —shorter, *Napaia gracilis* McN. —(*a*) Tempora visible from above, (*b*); —not. Fastigium without distinct median carina, *Orphulella*; —with distinct carina. Pronotum with distinct lateral carinæ, *Eonomus altus* Scud. —without, *Amphitornus ornatus* McN. —(*b*) Face and vertex as seen from the side not meeting at an angle, *Plectrotettix patriæ* Scud. —meeting in an angle. Tempora less than twice as long as broad, (*c*); —more. Prozona longer than metazona, *Bruneria shastana* Scud. —equal, *Stenobothrus oregonensis* Scud. (Fig. 9, B). —(*c*) Pronotum shorter than the head, *Eupnigodes megacephala* McN. —longer. Prozona longer than metazona, *Aulocara elliotti* Thom. —shorter. Tempora visible from above only on the inner half, *Psolessa*; —throughout their length, *Stirapleura pusilla* Scud.

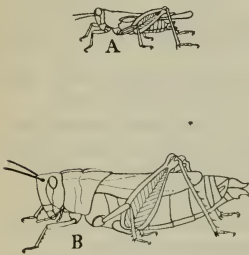


FIG. 9. GRASSHOPPERS.

(A) *Telmatettix aztecus* Saus.

(B) *Stenobothrus oregonensis* Scud.

*Orphulella*. Median area of front wings with two or three series of cells, *pelidna* Burm. —one. Lateral carinæ of prothorax divergent before and behind, *affinis* Scud. —parallel, *compta* Scud.

*Psolessa*. Sides of pronotum with feeble oblique carinæ, *texana* Scud. —none, *maculipennis* Scud.

*Edipodinæ*.—This subfamily contains quite a number of injurious species, but only one of them contributed appreciably to the injury this year.

Interspace between the metasternal foramina broader than long, (*a*); —longer than broad. Hind wings bright-colored at base, *Arphia*; —not. Middle median vein midway between the others, *Chortophaga brevipennis* Scud. —nearer the anterior. Head compressed, *Chimarocephala*; —rotundate, *Encoptolophus pallidus* Brun. —(*a*) Principal sulcus distinct on the sides of pronotum, (*c*); —feeble or wanting. Pronotal carina very slight, (*b*); —conspicuous. Pronotum rough, *Hippiscus*; —smooth, *Cammula pellucida* Scud. (Fig. 10, D). —(*b*) Front wings shorter than abdomen, *Agymnastus ingens* Scud. —longer, *Lepus*. —(*c*) Pronotal carina twice intersected, (*d*); —once or not. Costal margin of front wing thickened nearly to the tip, *Lactista gibbosus* Saus. (Fig. 10, G); —apical third membranous. No band on middle of wing, *Dissosteira*; —band present. Crest deeply intersected, *Spharagemon venustum* Stål.; —not, *Scirtetica occidentalis* Brun. —(*d*) Crest deeply intersected between sulci, (*e*); —not. Pronotum not crested in front, *Hadrotettix mundus* Scud. (Fig. 10, F); —crested. Sides of metazona narrowed beneath, *Derotmema*; —not. Lateral canthi of pronotum bending at principal sulcus or absent in front, *Mestobregma*; —not. Posterior veins of the hind wing swollen in the middle, *Circotettix*; —not. Crest as high on metazona as on prozona, *Conozoa*; —not, *Trimerotropis*. —(*e*) Middle independent vein evident, *Anconia integra* Scud. —lacking or feeble, *Heliastus*.

*Arphia*. Facial costæ not convergent above, *hesperiphila* Rehn. —convergent. Fastigium wider than long, *sulphurea* Fab. (Fig. 10, B); —longer than wide. Carina on pronotum slightly arcuate, *ramona* Rehn. —not, *behrensi*, Saus.

*Chimarocephala*. Body smooth, *behrensi* Saus. —rough, *pacifica* Thom. (Fig. 10, A).

*Hippiscus*. Carina of pronotum intersected by two sulci, (*a*); —by one. Spots obscure on tip of front wing, *californicus* Scud. —as elsewhere, *marmoratus* Scud.



—(a) Dark crossband on hind wings near the apex, (b); —far from apex. Metazona two thirds as long as prozona, *zapotecus* Saus. —twice as long, *pardalinus* Saus. —(b) Sides of pronotum slightly widening below, *neglectus* Thom. —not. Lateral canthi of prothorax absent on prozona, (c); —present. Markings of front wings obscure, *stigmatosus* Scud. —distinct, *aurilegulus* Scud. —(c) Metazona transversely wrinkled anteriorly, *lateritius* Saus. —not, *calthulus* Scud.

*Leprus*. Hind wings blue, *glaucipennis* Scud. —yellow, *intermedius* Saus.

*Dissosteira*. Disk of hind wings black, *carolina* Linn. —only obsoletely spotted, *spurcata* Saus. (Fig. 10, E).

*Derotmema*. Metazona distinctly broader than the eyes, *saussureanum* Scud. —scarcely broader, *delicatulum* Scud.

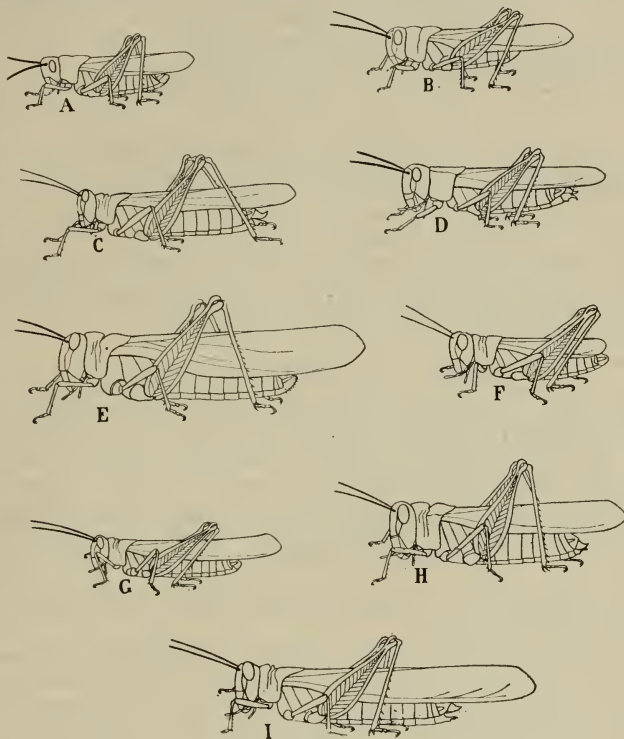


FIG. 10. GRASSHOPPERS.

- |   |  |
|---|--|
| (A) <i>Chimarocephala pacifica</i> Thom.      | (E) <i>Dissosteira spurcata</i> Saus.  |
| (B) <i>Arphia sulphurea</i> Fab.              | (F) <i>Hadrotettix mundus</i> Scud.    |
| (C) <i>Conozoa behrensi</i> Saus.             | (G) <i>Lactista gibbosus</i> Saus.     |
| (D) <i>Camnula pellicuda</i> Scud.            | (H) <i>Circotettix shastanus</i> Brun. |
| (I) <i>Trimerotropis pseudofasciata</i> Scud. |  |

*Mestobregma*. Median carina of pronotum crested between the sulci, *kiowa* Thom. —nearly obliterated. Front lobe cristate, *hyalinum* Scud. —not prominent, *rosaceum* Scud.

*Circotettix*. Hind wings not marked with black, *thallassinus* Saus. —black at base, *maculatus* Scud. —black band across the middle. Tip blackish, *suffusus* Scud. —mostly hyaline. Front wings conspicuously marked, *shastanus* Brun. (Fig. 10, H); —obscurely, *occidentalis* Brun.

*Conozoa*. Lower hind angles of the sides of the pronotum rounded, *wallula* Scud. —angulate. Crest of pronotum incised on prozona, *behrensi* Saus. (Fig. 10, C); —not, *sulcifrons* Scud.

*Trimerotropis*. Front wings banded, (*a*); -not. Sides of pronotum toothed beneath, *coquillettii* McN. -not. Ground color pale reddish brown, *hyalina* McN. -yellowish brown. Prozona of pronotum entire, *porrecta* McN. -bilobate. Crest of prozona in dentiform lobes, *rebellis* Saus. -rounded, *albolineatus* Brun. -(*a*) Front wings with basal and median bands solid and equaling following clear spaces, (*b*); -not. Hind wings hyaline, *pseudofasciata* Scud. (Fig. 10, I); -with indistinct dark band. Spots on front wings in clouds or bands, (*c*); -evenly scattered. Hind tibiae blue, *fallax* Saus. -not. Hind wings hyaline beyond the dark band, *variegata* McN. -dark, *conspersa* McN. -(*b*) Two black bands between the eyes, *cincta* Thom. -none, *juliana* Scud. -(*c*) Hind tibiae coral red, *californica* Brun. -whitish, *pacifica* Brun. -obscure yellow, *vinculata* Scud. -deep brown, *pilosa* McN. -blue. Metazona one and one half times as long as prozona, (*d*); -twice. Apical part of hind wings hyaline, *caeruleipes* Scud. -dark, *calignosa* McN. -(*d*) Ground color white, *albescens* McN. -brown or gray. Fastigium with median carinae, *bifasciata* Brun. -none, *kabelei* Brun.

*Heliastus*. Length of body ♂ 15 mm. ♀ 27 mm., *aridus* Brun. -much less, *californicus* Thom.

The insects of this last genus are commonly attracted by electric lights at night. Several species are highly injurious; and members of the smaller genera less often become troublesome.

*Acridinæ*.—This subfamily contains the greatest number of highly destructive grasshoppers. The two doing the greatest injury this year were *Edaleonotus enigma* and *Melanoplus devastator*.

Hind tibiae with apical spur on both sides, *Dracotettix*; -none on outside. Face nearly vertical, (*a*); -very oblique. Hind tibiae expanded apically, *Paropomala*; -not, *Arnilia mexicana* Saus. -(*a*) Mesosternal lobes longer than broad, *Schistocerca*; -equally long or broader. Hind tibiae with 6-8 spines on outer margin, *Dactylotum variegatum* Scud. -at least nine. Wings entirely absent, *Bradynotes*; -present. Pronotum with scarcely a trace of median carina, *Pæcilotettix coccinatus* Scud. -carina present and interrupted between sulci, *Edaleonotus enigma* Scud. (Fig. 11, B); -distinct and equal on pro- and metazona, *Hesperotettix*; -feeble on prozona, distinct on metazona. Pronotum as seen from above narrower in front, *Eoloplus*; -as narrow at the principal sulcus, *Melanoplus*.

*Dracotettix*. Median carina of pronotum scarcely stronger than the lateral, *plutonius* Brun. -distinctly, *monstrosus* Brun.

*Paropomala*. Front wing reaching tip of abdomen, *virgata* Scud. -not, *calamus* Scud.

*Schistocerca*. Pronotum obtusangulate behind, (*a*); -rectangulate. With dorsal stripe, *vaga* Scud. -none, *carinata* Scud. -(*a*) No dorsal stripe, *shoshone* Thom. -stripe present. Hind tibiae coral red, *venusta* Scud. (Fig. 5); -not, *alutacea* Harr.

*Bradynotes*. Interspace between mesosternal lobes considerably wider than the lobes, *satur* Scud. (Fig. 11, A); -scarcely. Pale lower portion of sides of pronotum contrasting with dark above, *referta* Scud. -not, *obesa* Thom.

*Hesperotettix*. Front wings much shorter than abdomen, *pacificus* Brun. -equal or longer. Legs green, *pratensis* Scud. -buff. Transverse sulci of pronotum marked with black, *viridis* Thom. -not, *festivus* Scud.

*Eoloplus*. Front wings longer than the abdomen, *californicus* Scud. -shorter, *chenopodii* Brun.

*Melanoplus*.\* Front wings about equal or longer than abdomen, (*c*); -much shorter. Cerci broadest beyond middle, (*b*); -not. Cerci broad and short, *rileyanus* McN. -at least as long as broad. Subgenital plate short and broad, *varicus* Scud. -distinctly narrower than long. Cerci gently tapering, *gracilipes* McN. -abruptly. Front wings longer than pronotum, *phataliotiformis* Scud. -shorter. Subgenital plate tuberculate at tip, *fuscipes* McN. -not. Hind margin of pronotum emarginate in the middle, (*a*); -not. Tapering portion of cerci about as long as basal portion, *pinctus* Scud. -about half as long. Lateral carinae of pronotum distinct, *borckii* Stål. -indistinct, *pacificus* Scud. -(*a*) Color ashy, *tenuipennis* McN. -dark brown, *missionum* Scud. -(*b*) Inter-

\*This synopsis refers only to the males; the females in this genus are difficult to distinguish from each other.

val between mesosternal lobes about twice as long as broad, *ascensus* Scud. —about square. Subgenital plate longer than broad, *ablutus* Scud. —short and broad. Cerci about as long as supraanal plate, *ligneolus* Scud. —much shorter, *nanus* Scud. —(c) Cerci broadest beyond middle, (*g*); —not. Furcula truncate at tip, *flavescens* Scud. —pointed. Three or four times as long as broad, (*d*); —not over twice. Median groove on supraanal plate disappears toward the tip, *atlanis* Riley; —reaching the tip, *spretus* Uhler. —(*d*) Subgenital plate narrowed at apex, *femur-rubrum* DeG. —not. Interval between mesosternal lobes twice as long as broad, (*e*); —about half as long as broad. Cerci not narrowing toward the tip, *ater* Scud. —narrowed. Cerci sulcate on the outside of tip, *sierranus* Scud. —only dimpled, *consanguineus* Scud. —(*e*) Front wings without spots, (*f*); —spotted. Pronotum with distinct pale stripe interrupting the black band on the side near the front edge, *virgatus* McN. —not, *devastator* Scud. (Frontispiece). —(*f*) Whole body light colored, *uniformis* Scud. —dark, *angelicus* Scud. —(*g*) Cerci bifurcate at tip, (*i*); —rounded. Furcula much longer than its segment, (*h*); —scarcely. Supraanal plate suddenly bent down beyond the middle, *packardii* Scud. —all in one plane, *marginatus* Scud. —(*h*) Furcula narrowing uniformly, *cyanipes* Brun. —sides of part of the tip parallel. Color markings feeble, *dealbatus* Scud. —distinct, *cinereus* Scud. —(*i*) Furcula absent, *differentialis* Uhler; —present. Interval between mesosternal lobes less than twice as long as broad, *olivaceus* Scud. —more, *femoratus* Burm.

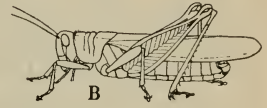


FIG. 11. GRASSHOPPERS.

- (A) *Bradynotus satur* Scud.  
(B) *Edeletonotus enigma* Scud.

## GRASSHOPPERS IN FORMER YEARS.

The earliest history of grasshoppers in California appeared in Clavi-jera's History of California. He noted insects as injurious to Mission property in 1722, 1746, 1747, 1748, 1753, 1754, 1756, 1766, and 1767. His account of these insects is very elaborate and interesting, though, of course, full of errors as to their life history\*.

After these dates there appears to be no record of grasshoppers for half a century, though there is no reason to doubt their continued injury. The dates during the rest of the Spanish occupation of the country are, 1823, 1827 or 1828, 1834 or 1835, 1838, 1839, and 1840†.

After the American control, the first record of their appearance (omit-ting 1849, mentioned by Taylor without locality) is in June and July, 1852, in the marsh lands on the east side of San Francisco Bay‡, which we believe is also the latest record of injury by hoppers in this region; and the time of the year suggests that it must have been some other species than the one now dominant there.

In 1854, on the Wolfskill ranch on Putah Creek, and on the American River near Sacramento, hoppers became troublesome, and there was near San José a swarm of what must have been crickets, covering the ground for miles§.

The year 1855 witnessed the greatest invasion of grasshoppers that has been experienced since the American occupation, at least in the

\* A. S. Taylor, in California Farmer, January, 1853, p. 18.

† Ibid. February, 1853, p. 34.

‡ L. G. Yates, in first report U. S. Ent. Comm., 1878, p. 451.

§ Colonel Warren, in California Farmer, August, 1854, p. 52.



cultivated portion of the State. The accounts in the California Farmer, the Sacramento Union, and the Shasta Courier of that year, show that the pest did its greatest injury about Sacramento, though it extended all over the State. Much injury had already been done and the insects were flying in great swarms as early as the middle of June, and migrations occurred in the northern end of the Sacramento Valley as late as the middle of September.

Following this we have the dates 1856 in Mariposa and Fresno counties, 1859 in Modoc and Sutter counties, 1862 or 1863 in Modoc County, 1866 or 1867 in Stanislaus County, and 1869 in Tulare County, as collected by the U. S. Entomological Commission\*; and in 1857 when a swarm fell into Suisun Bay on the 14th of July†. In 1858 hoppers were bad in Monterey County, and in Siskiyou County large crickets, as they were called, appeared in June and July‡.

The remaining dates are mostly taken from the Pacific Rural Press of the years given, and from records in our office:

1870, in Yolo County;

1871, in Tulare County;

1877, in Sonoma, Sierra, San Joaquin, Fresno, Santa Barbara, and San Diego counties;

1878, in Sierra County;

1879, in Sierra and San Joaquin counties;

1880, in Sierra County;

1882, in San Luis Obispo County;

1883, in Kern County;

1884, in Butte, Sacramento, El Dorado, Sonoma, and Mendocino counties;

1885, in Napa, Yolo, Sacramento, Merced, and Fresno counties;

1886, in Yolo and Fresno counties;

1887, in Sacramento County;

1888, in Sacramento and Santa Cruz counties;

1889, in Solano and Tulare counties;

1890, in Shasta, Yolo, Nevada, and Santa Barbara counties;

1891, in Butte, Sutter, Sacramento, San Joaquin, Stanislaus, and Kern counties;

1892, in Tulare and Kern counties;

1896, in Kern County;

1897, in Glenn County;

1898, in Alameda and Santa Clara counties.

These dates are certainly incomplete. In many sections grasshoppers are so common that they do not cause comment. With one or two

\* 1st Report U. S. Ent. Comm., p. 453.

† A. S. Taylor, in California Farmer, January, 1858, p. 10.

‡ Ibid. February, 1864, p. 11.



exceptions we do not have access to any of the southern California dates, but know that they are often troublesome there. That which is given will be enough, however, to show that grasshoppers are almost constantly doing damage in some part of the State.

#### LIFE HISTORY.

There is yet so much to be learned in regard to the life histories of the injurious species of grasshoppers in this State that no very satisfactory account can be given. The process of egg-laying has been observed in the case of certain of our species by farmers and others, but no accurate observations have been made as to the manner in which it is done, nor the places chosen for this purpose. As far as known, our species have similar habits in this particular as the *Melanopus spretus*, which is the most injurious species east of the Rocky Mountains, and which has been very carefully studied. From these observations and the distribution of young hoppers, we can infer that uncultivated land is almost exclusively selected. This accords also with what is known of the habits of the injurious species of the Eastern States. It is likely that the egg-laying period extends over at least two months, being probably at its height, in the case of our best known *Melanopus devastator*, about the first of August in the Sacramento and San Joaquin valleys. In some localities, as at Berkeley, egg-laying does not commence until the latter part of August or first of September.

All of our very injurious species pass the winter in the egg condition, though some kinds of grasshoppers are hopping about all through this season. The hatching of the egg in the spring has never been carefully observed and described. The very young hoppers are so small that they usually escape attention. The time of hatching probably varies even more than the time of egg-laying.

While the grasshoppers are young, even when very abundant, they do not do an appreciable amount of injury to grass, upon which they chiefly feed. They are so active, moving about between meals and distributing their attack, that any one plant is only slightly injured at one time, and is generally able to grow rapidly enough to keep ahead of the work of the hoppers. Young hoppers do not seem to require a great quantity of food, probably because of their rather slow growth. During their growth they change their skin from time to time, probably going through this process, as does the Eastern species, five times before obtaining their wings.

*Breeding-Grounds in California.*—The grasshopper situation on this side of the Rocky Mountains differs very decidedly from that on the other. Here there is really no plateau region corresponding to the great plains of Colorado, Montana, and Wyoming. The grasshoppers that do injury

are all developed within the State, since it is pretty well demonstrated that the hoppers do not cross the high Sierras from Nevada, where they are also destructive. The danger from hoppers in this State arises from a comparatively narrow strip of rolling and hill land used for pasture purposes. This forms a strip bordering on the east of the Sacramento and San Joaquin valleys, and to a less extent along the hills of the Coast Range; in southern California along the hills to the north and east of the cultivated region. These breeding-grounds are nowhere many miles in width, and present a considerable diversity of conditions, in consequence of which the hoppers but seldom become excessively abundant over any considerable area at one time. We need not therefore expect the insects ever to become so abundant as to occur in such overwhelming numbers as they sometimes do on the other side of the Rocky Mountains; but on the other hand, it is also true that with our diversity of situation and of species we may expect much more frequent injury from hoppers than will occur there. This will come to be more and more apparent as our orchard area continues to expand, for at present, as in the past, the large grain fields offer a partial protection, lying as they usually do between the breeding-grounds on the pasture lands and the orchards where the most serious injuries are done. As fast as orchards replace these grain fields, the danger of injury from the smaller swarms, which in times past have been held back by the presence of the wheat fields, will come more and more in evidence.

*Drifting.*—When the young hoppers are unusually abundant, or the food-supply begins to dry up and become scarce, they are forced to move about more than usual in search of new food, and this they accomplish by jumping and walking about. The direction that they pursue is entirely a matter of accident, unless it should happen that a gentle wind is blowing, in which case they will all be seen to be moving in one direction. The reason appears to be that the insect dislikes to stand with its side to the wind, but after a leap will turn itself about and face the wind, and the next time it leaps it will naturally leap in the direction from which the wind is blowing. While walking the insect pursues the same course.\* In hollows or sheltered places the hoppers will gradually accumulate if hopping toward the wind, so that ultimately instead of being evenly distributed over the breeding-grounds they will begin to gather in great swarms. These will rapidly eat the available food they come to, and will be forced to migrate more continually than they would if not massed in swarms. The hoppers may in this way leave their breeding-ground *en masse*, and traveling

\*There appears to be no such definite rule in the case of the Eastern species, and in the East the direction of migration is considered an unsolved mystery. The account given here accords with all the observations made this year, but it is possible that further study will show other causes that may at times determine their direction.

straight across the country, devour the orchards, vineyards, and ornamental plants that may come in their way. This form of traveling should be distinguished from the true migration, which occurs after the insects obtain their wings. We have suggested and used the term "drifting" to distinguish this movement from migration by flight. Drifting may also occur after many of the insects have obtained their wings, the insect hopping, walking, and flying for short distances against the wind in the manner just described.

*Migration.*—When drifting swarms are large and the food-supply correspondingly meager, winged grasshoppers will, under the proper atmospheric conditions, suddenly, as by a common impulse, rise high in the air and travel for many miles in a dense swarm. This is the true migration. These flying swarms are the ones best known in the literature of grasshopper work, and it is the only form with which regions distant from the breeding-ground become menaced by grasshopper invasions. Exactly what conditions cause insects to rise for the migration is not well understood. Those who are well acquainted with the phenomena in this State have described the condition to us in these terms, "When the hills look unusually blue the hoppers are extremely liable to take to wing." Usually it is the settling of the insects from the sky that has been most commonly observed. It is likely that the purpose of migration is entirely identical with that of drifting, with the exception that under the peculiar atmospheric conditions the hoppers have a tendency to fly unusually high, and are there met by a current of air which will sweep them down over the valley until they, for equally poorly understood reasons, decide to alight. The U. S. Entomological Commission has collected an immense amount of data in reference to the flights of the swarms of grasshoppers of the species *Melanopus spretus*, but is not able to determine very accurately the details of the process, or find explanations for the cause, amount, or direction of the motion. Only in a general way it appeared that hoppers which come to maturity in the higher arid regions usually fly southeast toward the valley of the Mississippi, while those hatching in the low lands, and coming to maturity somewhat earlier because of the warmer climate, usually migrate in the opposite direction.

These differences in direction correspond somewhat with the prevailing direction of the winds at the times of the two sets of migrations. The observations in this State are still extremely meager, and the distance between the center of the Great Valley and the breeding-ground is so slight, that it is not strange that we have not recognized here any distinct return migrations. As far as we are aware the hoppers have never developed in injurious numbers in the orchard region, and we are inclined to think that we need not usually fear an attack a second year in the same locality.



## REMEDIES.

Grasshoppers are insects unusually difficult to control. They often occur in such overwhelming numbers that it is really impossible to do anything that will be effective. Fortunately, in California such numbers will be of extremely rare occurrence, on account of the very limited breeding-grounds from which any particular swarms may come. While they will not with us be so absolutely uncontrollable, still it remains an extremely difficult problem. The fact that a method very efficient under one set of conditions will be entirely valueless under others, still further complicates the subject.

We can recognize three very distinct sets of conditions, each of which will demand an entirely different programme:

I. *Control of the Flying Swarms.*

When grasshoppers come into an orchard after a true migration, the difficulty of the situation lies largely in the suddenness of their appearance, a fruit-grower often being quite unaware of the danger before the hungry hoppers have descended upon his crops. Usually, therefore, what can be done must be done very quickly. Available means can be grouped under the heads of "Driving" and "Poisoning."

1. *Driving.*—There is considerable evidence that the use of smudges, at the time that the insects are alighting, may cause them to pass over and beyond the protected fields. Usually this measure will not entirely protect the fields in which it is used, and becomes less and less effectual if the swarm comes slowly, as is sometimes the case, when they may be for hours alighting; or, on the other hand, if they come on successive days. In either of these cases smudging will not commonly drive enough away to be of material benefit. Under favorable conditions, swarms may in this way be so dissipated that the hoppers will not be in very destructive numbers in the protected field; and perhaps if the swarm is not too large it will be prevented from doing material injury.

Since so many of the swarms in the State are of small size the smudging process is really quite an important addition to our list of available remedies. The method of smudging is to build fires on the windward side of the fields to be protected, making as dense a smoke as possible and so placing the fires as to keep the fields as completely as possible covered by the smoke of the smudge. It is also the practice to add from time to time small quantities of sulfur to the burning smudge-piles. If care is had this can be used without any danger to the trees. If sulfur is used, however, it should be clearly understood that there is more or less danger to the foliage, especially that of the younger plants, and that corresponding care must be exercised.



Another driving method is by frightening the insects out of the field by putting in a gang of men and, beginning on the windward side, gradually work back and forth across the field, thus scaring the hoppers ahead of them. The walking of the men through the field may be



FIG. 12. THE USE OF SMUDGE TO PROTECT VINEYARD.



FIG. 13. APPLICATION OF SULFUR TO SMUDGE FIRES.

sufficient for this purpose, but commonly short sticks, to each of which a piece of cloth is attached, are used to frighten them more effectively from the plants, which may be at the same time jarred or lightly beaten. In this method, as well as in the smudging method, the idea is not to rid the orchard completely of the insects, but to drive out sufficient

numbers, so that the remaining hoppers may not injure the plants to a serious extent.

2. *Poisoning*.—In addition to the method suggested above, more or less satisfactory results can be obtained by the use of poisons, either applied as a spray to the plants or in the form of poisoned bran mixture, described below. This method of poisoning will not be as effective against winged insects as it is against the drifting swarms, for which it was originally devised.

Flying insects are not as readily attracted to the bran mixture on the ground as are hopping insects. They are quite commonly in greater numbers and do their work more rapidly, and therefore the method can seldom be depended upon, if used by itself. It is, however, a very useful supplementary measure to that of driving, just referred to. It is possible that the use of poisoned paper placed in the vines or trees would prove much more satisfactory than the bran mixture, which of necessity must be placed chiefly upon the ground. At least, this is a point well worthy of investigation.

The paper used should not be glazed; newspapers or straw paper would be good for the purpose. The best way to treat the paper is to unroll it on the ground and apply the poison with a garden sprinkling pot. The arsenic should first be dissolved by boiling with four times its weight of sal soda, and then mixed with molasses. The proportions are, for each pound of arsenic, two gallons of water, four pounds of sal soda, and two gallons of molasses.

## II. *Control of Drifting Swarms.*

Cultivated ground immediately adjacent to the breeding-grounds is always more or less subject to injury from drifting swarms, even when numbers are not sufficient to cause the true migration. The hoppers go into the fields slowly enough when drifting in this way, to give plenty of time for the farmer to plan and execute the defense. The chief difficulty lies rather in the fact that very often hoppers will continue to drift out of the breeding-ground for weeks at a time, so that the fight is a long continued one. The means that have been employed with greater or less success against drifting swarms consist of barriers, smudging, sacking, plowing-in, poisons, and the use of the hopper-dozer.

1. *Barriers*.—A great many plans have been tried to prevent the entrance of hoppers from breeding-grounds. That which has been used on the largest scale in other countries, though we believe as yet not used in California, is fencing them out. Usually a strip of cloth a yard wide, reaching to the ground, will be found an effectual barrier as long as the insects are wingless. If a fence is used there should always be other means for actually destroying the insects, because otherwise they will be

able to climb to the top of the fence and hop over. The use of the fence then, like all the barrier methods, is a scheme for assembling the hoppers (thereby making their destruction easy) rather than a means effective in itself. These cloth fences, when properly managed, are probably the most effective of all the barrier plans. In connection with the fence, or even without the use of the fence, very good results are obtained by the use of furrows, in which the hoppers will accumulate and may be destroyed by dragging a heavy log along the furrow. Very commonly this furrow method is used without fencing, and has proven effective, in this State, in a few cases where the swarms were small but dense. The furrow should be plowed deep, with its steep or land side toward the ground to be protected; and it requires considerable and continuous attention to prevent the hoppers from passing over.

2. *Smudging*.—When hoppers are not too abundant, injury has sometimes been quite avoided by the use of smudging. The object in this case is to scatter the insects so as to prevent their eating up the immediate border of the fields adjacent to the breeding-ground. Very commonly one or two rows of the orchard or vineyard will be destroyed and the trees or vines beyond remain uninjured. By the use of a smudge the hoppers can be, in part at least, caused to move on, so that by distributing their injury no trees or vines will be seriously eaten. Young hoppers do not “move on” as readily in response to the smudge as do the winged insects, and it may be necessary in connection with it to jar them from the trees and vines upon which they have gathered.

3. *Sacking*.—In almost every season that hoppers have appeared, the sacking method has been resorted to with varying success. Sometimes the trees have died within the covering, sometimes the coverings have proved to be insufficient to keep out the hoppers, and at other times the plants, while appearing all right at the time the sacks were removed, have suddenly, after their removal, cast their leaves and lost their new growth, if not dying outright. The material used in sacking has been extremely variable, being sometimes as heavy as grain sacks. With our present knowledge and with the extremely variable results obtained, it is impossible to make any definite recommendation. At best it is an expensive operation, and will probably not be generally resorted to except as a protection to plants of more than ordinary value, or to newly set orchards where very small coverings will be sufficient to inclose the green parts. When this method is used, injury to the plants can be avoided by carefully watching the conditions, and removing the covering in the same way recommended in the case of vineyards plowed-under. As soon as there is the beginning of any sign of yellowing of the leaves the covering should be removed and other means of protection resorted to. Whether there will be any of this yellowing will depend



upon the condition of the plant and of the weather during the time the covering is on.

In removing the coverings the death of the plant can usually be avoided by a gradual instead of a sudden removal. Injury in a case of removal is usually or always caused by the tenderness of the foliage on the new growth, induced by the protection afforded by the covering. If the covering is gradually removed, and the plant brought into the outside air a little at a time, the leaves will slowly adjust themselves to the outside conditions.

4. *Plowing-in.*—When the drifting swarm attacks a newly planted vineyard it is sometimes possible to accomplish good results by covering the latter up by means of the plow, throwing a furrow over it from each side. This may prove perfectly feasible and efficient if the hoppers are moving in a distinct swarm and the source of supply is at a distance, or so located that the hoppers will not be likely to continue coming for a long period.

The only question will be that of the ability of the vines to retain their life beneath the ground long enough to allow the hoppers to pass by. The vines will ultimately be killed unless uncovered. The length of time that they can stay underground will vary according to the temperature and character of the soil. One can keep watch of the vines thus plowed-under, and uncover them as soon as he sees evidence of the beginning of injury. If by this time the hoppers are gone or have passed on, the method will be satisfactory.

5. *Poisoning.*—The most effective means for killing young hoppers has been the use of poisons. The method most commonly used is the bran mixture containing sufficient arsenic to kill them, and enough attractive sticky material, as molasses, or sugar solution, to hold poison on the bran. The formula used quite extensively this year was bran forty pounds, molasses two gallons, arsenic five pounds, and water about six gallons. The whole was very thoroughly mixed and applied by means of a spoon or paddle, about a teaspoonful at the base of each vine or tree. The formula is often varied, sometimes by using twice or four times as much arsenic, but the amount here given is amply sufficient to kill. Indeed, it would probably be quite as effective if the arsenic were greatly diminished in quantity. The most important point in its preparation is the thorough mixing of the material. The poison may be well stirred into the liquid used, or even into the dry bran; but in either case the mixing must be thorough before the bran is wetted, for otherwise the mixture will not be uniform. The best method is to mix the ingredients in the same manner that mortar is hoed or shoveled. It is quite probable that if the arsenic were first dissolved, and its solution used in mixing, a greatly diminished dose of arsenic



would be sufficient; but as arsenic is cheap, and the mixing of the dry powder is so much easier than making a solution that will require boiling, it is likely that the dry arsenic is the most economical.

In the use of this mixture it is well not to lose sight of its poisonous nature. Stock are particularly liable to be poisoned, so every precaution should be taken to prevent their eating it. Hoppers are not at once killed after eating it; they will usually show no effect of poisoning for several hours, and it may take a day or two before an insect that has had a poisoned dose will actually die; but they cease to eat long before death occurs. As far as could be estimated the rate of dying is about as follows: after twenty-four hours, one quarter of the hoppers are dead; in forty-eight hours, nearly one half. Others continue to die after this, but at least twenty-five per cent apparently fail to feed upon the poison



FIG. 14. DEAD GRASSHOPPERS IN A HOPPER-DOZER, COLLECTED IN A VINEYARD.

at all. The reduction in number, even if it should not be over one half of those attacking the vines, will in most cases be enough to prevent the destruction of the latter. When the hoppers are very abundant it will not do to depend wholly upon any one method of treatment, and so, while poisons are the cheapest and perhaps the most effective single means of treatment, it is advisable to supplement it with other plans.

*The Use of the Hopper-Dozer.*—When the hoppers are excessively abundant it will pay to use the hopper-dozer in the orchard or vineyard; it may be necessary to make one of especial size or shape for this purpose. It may be useful also to drive the hoppers more or less by the use of the cloth on a stick, as described above, the idea being to cause the hoppers to jump from the trees or vines onto the ground, or better

still onto the hopper-dozer as it passes. Quite effective work was done this year in the vineyard by three men, one driving the dozer and two working along on the opposite side of the adjacent rows of vines, causing the hoppers to jump on the dozer. The use of the hopper-dozer in the orchard is thus much more troublesome and really a good deal less effective than in meadow or pasture lands, but will undoubtedly pay well where hoppers are more than usually abundant.

It is likely that hoppers will never be in so great numbers in this State but that, with the use of the remedies here suggested, they can be prevented from killing orchard trees or grapevines.

### III. *Control in Breeding-Grounds.*

It is probable that a careful investigation of the life of the insect will show that in every part of California it is entirely possible to destroy the insects very economically in their breeding-grounds, to such an extent as to reduce the probability of injury to adjacent fields almost to nothing. Indeed, it seems that the real solution of the problem toward which we should strive, is that of the control of the insect in its breeding-ground. The methods that have been employed most effectively have been plowing in the winter, the use of the hopper-dozer while the insect is still young, and burning after the grass becomes sufficiently dry.

1. *Plowing.*—The plowing of the breeding-ground is the favorite method on the other side of the Rocky Mountains, where work against hoppers has been longest under way, especially in the northern part of that hopper region. It is found that plowing, in the fall, the ground in which hoppers have been observed to be depositing their eggs in more than usual numbers, almost entirely prevents their hatching the following spring. It may be that the same will be found true in California; certainly the observations of this season indicate that the young hoppers do not exist in grain fields or winter-fallowed land, or indeed anywhere except on uncultivated roadsides and pasture lands. The economical use of this remedy requires careful observations of the egg-laying in the fall, because it will not pay to plow large tracts of land only slightly stocked with hopper eggs. It may be found, indeed, that this method is only applicable to roadsides; but its efficiency in other regions indicates that it should be given a very thorough test under our conditions.

2. *Burning.*—Our observations of the burned areas this year, and the uniform testimony of those who have burned in this and in preceding seasons, agree as to the thorough efficiency of this method of ridding breeding-grounds of grasshoppers. The method can not be used early

in the season, because the grass is not dry enough to be completely burned off, and the hoppers will be most abundant in parts of the field not burned. Indeed, burning can not be used until the hoppers have already begun to drift. When the time comes for burning, therefore, it must be done at once. Usually only two or three weeks are available



FIG. 15. BURNING THE BREEDING-GROUNDS TO KILL GRASSHOPPERS.



FIG. 16. FIELD AFTER BURNING, SHOWING HOW COMPLETELY BARE THE GROUND IS MADE.

for this purpose during the season. Of all methods of hopper control this is the one that can be applied most readily, and large areas can be very quickly treated in this way.

The method is not without its objections, however, the chief of which is probably the losses covered by the destruction of pastures. As to how great this loss is there is difference of opinion; some claiming that



it really amounts to very little, since a new growth will take place as soon as the rains come; and some pasture lands are regularly burned over and remain well stocked with grass. Others contend that unless the rainy season is particularly wet a large percentage of the seed in the soil will fail to germinate, and that the destruction of the seed on the surface also decreases the grass to such an extent that it requires several years of ordinary rainfall before the pastures are able to carry their normal quantity of pasturage. Still others claim that even if the succeeding season is unusually good, the destruction of the seeds is so great that the pasturage does not come up to the normal for several years. It is probably safe to assume that there will be considerable loss from burning. Indeed, the action of the railroad companies in settling for a considerable bill of damages, in case of the accidental burning of pastures from sparks from the engines, is very good evidence that loss is produced.

If burning is adopted as a method of fighting grasshoppers there should be ample provision made whereby those whose lands are burned over are indemnified to the extent of the loss suffered. We are inclined to think that this method of fighting grasshoppers should be adopted only as an emergency measure, in case other methods fail, and only when the hoppers are in such great numbers as to constitute a very serious menace to adjacent fields, or when the area is so large that there is great danger of flying swarms being developed.

3. *Hopper-Dozers.*—The use of the hopper-dozer upon the breeding-ground is a method which at the present time promises most for the control of grasshoppers. There is a long period, at times two or three months, in which it can be used. The cost of its application is really very slight. Its effectiveness has been demonstrated in many hopper regions, though never extensively used in California. The lands in which the insects appear are open, rolling ground upon which the hopper-dozers can be easily used, so that this appears to present the most practical means of hopper control at our command. The hopper-dozer is very simple in construction, consisting of a shallow galvanized iron pan of any convenient dimension; those in use the last season under our directions were about six feet long by three feet wide, with the edges turned up about one inch. These pans are mounted upon wooden runners, one inch thick, shod with hoop irons beneath and having along their back a vertical screen of cloth intended to prevent the hoppers leaping entirely over the pan. The construction of these pans will be very clearly understood from the figures on page 33.

In the bottom of the pans crude oil is placed. This is usually prevented from flowing and splashing out by a layer of cloth, such as grain sacking. In front of this apparatus at a convenient distance, say about a foot, there is hung a light pole, which drags upon the ground and



frightens the hoppers. As they jump into the air they are caught upon the pans and wetted with the oil. Very often they again hop out of the pan, but will usually have gotten enough oil upon them to cause their death; a great many die in the pans, so that they have to be emptied and new oil added from time to time. The amount of oil used is really a small item, however, and a great deal of territory can be covered in a single day. It is better in using the hopper-dozers to have a number following each other like the plows in the gang-plow, so as to sweep large swaths across the field. Under favorable circumstances a large percentage of the hoppers will be killed by once going over the fields. It may be desirable, however, in most cases to repeat the operation once

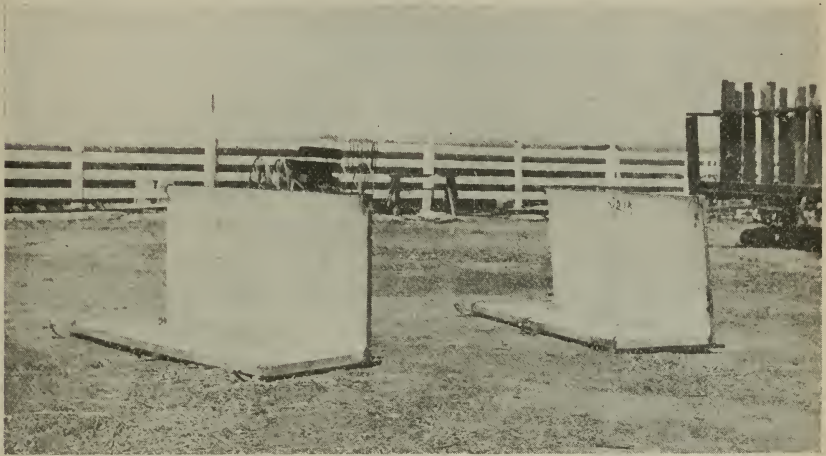


FIG. 17. HOPPER-DOZERS FOR DESTRUCTION OF GRASSHOPPERS.

or twice. With the proper inspection of the breeding-grounds in the State, and the use of hopper-dozers under competent direction, it would seem possible to entirely control the insect.

#### COMPLETE CONTROL.

The hopper question can not be considered as finally settled until the insects are brought under practically complete control. This complete control, as already indicated, can only be accomplished by attacking them in their breeding-grounds. Every one will realize that this is a work demanding concerted action, and that individual effort can not be depended upon to accomplish the result. Usually if local initiative be depended upon the fight will be delayed until the actual injury can be seen, when it is too late to accomplish the best results, and what can then be done will require a vastly increased expenditure.

The presence of hoppers in their breeding-grounds in sufficient num-

bers to cause great damage when they drift into adjacent vineyard lands will scarcely injure the grass of the pasture. The owners of these lands can hardly be expected to do anything when the amount of injury done there is so small as to be quite out of proportion to the cost of the destruction of the hoppers. Those whose properties are most menaced should bear most of the cost of the extermination of the insects; or rather it is a matter of general property interest that should be attended to by the district, the county, or the State. This is clearly recognized in other States, and there has been much grasshopper legislation. But the scheme developed in another State would not be likely to fit our conditions and might be very inappropriate.

A suggestion that has in several instances formed an important item in these laws is the offering of a bounty for the destruction of the hoppers. This plan has nowhere proven very satisfactory, and this State has had an experience with bounty legislation in another matter, which it is not anxious to duplicate. The difficulty with this plan arises from the fact that while it is continually an expense, work will never be done thoroughly enough to accomplish the results aimed at.

#### A PLAN FOR STATE ACTION.

A plan which seems to meet the needs of the case in California involves, first of all, an ample provision for the careful study of the breeding-grounds and habits of young hoppers, in order that we may know which are the places where the hoppers are likely to become abundant, and where we can prepare to take measures against them in the seasons of their unusual prevalence. This provision should be made at once, so as to be ready for the next season of hopper injury. This study should include a careful mapping of these grounds, and the preparation of a working plan for future control work.

*Hopper Reporters.*—The knowledge thus obtained should enable those in charge of this work to secure, by means of correspondents in each locality, reports which would give early information of the first appearance of hoppers in unusual numbers. It may be possible to ascertain the localities and to determine the kind of locust which is liable to increase to injurious numbers corresponding with the character of the season; and thus to be able to so direct the observation of those living in such localities as to obtain from them full information at a time when otherwise they would not be likely to observe their presence at all.

This securing of early information is the key to the whole situation, because with it the suppression of the hoppers can be planned and executed before they begin to do any injury at all. It will be impossible to have enough trained investigators in the field to accomplish much in the way of keeping track of the abundance of the insect, but with the

necessary information furnished to those living in these threatened localities, there is no reason why in every neighborhood persons could not be found who could make satisfactory reports.

*Competent Inspection.*—The information secured by correspondents in this way will be very unsatisfactory, unless there are also provided, at the same time, competent inspectors, who will visit the grounds where hoppers are reported as being in excessive numbers. These inspectors should very carefully inquire into the situation and determine accurately the relative numbers and the range of the insects.

If this is done early enough it will be possible to plan out a campaign which will enable the people of that locality, in most cases, to so reduce the numbers that the danger of migration will be nothing. The ability to make accurate observations in this matter will require that the inspector making this final inspection shall have acquired a good degree of knowledge of the conditions of the insects in ordinary years, so that he will not be misled on the one hand into thinking that the hoppers are not in dangerous numbers, or on the other hand, into suggesting the expenditure of time and money for the destruction of the hoppers when in reality there is not sufficient danger.

*Supervision.*—After this knowledge has been secured it will be necessary, in order to produce the best results, that the efforts that are made for the suppression of the insects shall be under the immediate supervision of a competent officer. The need of careful supervision of this work arises chiefly because in this way the most economical fighting can be done. It is not merely a matter of choosing the right remedies, but of knowing when and where to work to the best advantage, and where it will be safe not to make any effort at all. There is no doubt that in the past year, where burning has been resorted to, a great deal of the territory has been burned over that had no sufficient stock of hoppers upon them to justify any kind of treatment. If left to local initiative it is entirely likely also that expensive methods, like that of burning, will be the ones usually chosen when cheaper methods would be equally efficient.

*Local Authority.*—It will be imperative, if the hopper situation is to be controlled in the State, that the laws be so amended that there will be definite provision giving some one in each locality the power to conduct the local fight against the hoppers. Perhaps the best way in which this can be accomplished would be to definitely enlarge the powers of the county horticultural boards and specifically make it their duty to look after the hoppers of their county. This has worked very satisfactorily in the grasshopper fights of other States, and there seems no reason why this machinery already created in this State should not be utilized in this way. There will really be no need of creating any new powers, but merely making the powers we have now for fighting scale



insects apply also to the fighting of the grasshopper pest. Of course it should be also clearly understood that in this matter these county commissioners shall work under the directions of the competent supervision insisted upon above.

*State Authority.*—The experience this year in Sacramento and adjacent counties shows that it is very important for the success of this work that there shall be a central authority, equally powerful with the local authority, whose duty it shall be to undertake work where adjacent districts are in danger and where the local authority neglects or fails to act. As the horticultural law now stands there is no one who has any power to step in between counties and prevent the inaction of one resulting in a loss to the other. When the horticultural laws were framed the insects had in view were the scales, which are very slow and poor migrants, so that there was scarcely any danger in one county from the neglect of the authorities of the other. With the grasshopper the situation is entirely different. This matter would be put in the proper shape if the State Board of Horticulture were given the same powers possessed by the county boards, which at present the law expressly denies it.

*The Plan in Brief.*—In all this work it should be clearly recognized that there are two distinct things to be provided for:

1. Investigators who will secure data regarding the hoppers, direct those charged with their destruction, and advise regarding the best means to pursue—in short, to serve as a source of information.

2. An executive body with the legal power to enter premises and to do everything needful to accomplish the destruction of these pests.

It is a good thing to keep these two functions entirely distinct. For the latter, a very slight modification, as suggested above, of the laws relative to our Boards of Horticulture would provide a very satisfactory machinery for accomplishing the results. For the former work there might be established, as is done in many of the other States afflicted with grasshoppers, an office of State Entomologist, whose duty it would be to investigate injurious insects and to distribute the information, particularly that of fighting grasshoppers. In some cases this officer is also the Entomologist of the Experiment Station, but when this is the case it is recognized that the work is not wholly such as would be suitable to be classed as Experiment Station work; so that in every State where this connection is maintained provision is made for the extra work by suitable appropriation to cover the cost of such investigations.

California is the only State among those affected by grasshoppers, in which there is hope for the complete control. Such control does seem quite possible here, if adequate means are employed to accomplish it, following more or less the lines suggested above.